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The internalization of external costs of CHP plants in Croatia

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Abstract

In order to achieve the cost-optimal level, from the social point of view, the state/government seeks to internalize the external costs, considering that it would be an incentive for investors to behave more responsibly to the environment and society as a whole. Specifically, more technologically advanced power plants significantly reduce emissions, use less fuel to run, generate less waste, and thereby reduce the amount that an investor has to pay for the internalized external costs. However, internalized costs affect not only the decision for the construction, hence the security of future energy supply, but also the production cost of energy (and consequently the selling price), and thus the overall economic and social activities in a country. Therefore, the issue of internalization of external costs is of great importance for both investors and sustainable economic growth and development of each country.

The main objectives of this paper were to investigate and estimate internalized costs an investor in combined cycle heat and power (CHP) plant in Croatia has to pay for the first project year, and to determine their share in the operating cost structure of energy generation for that year. To define the various social costs associated with energy generation, the impact pathway approach within the ExternE methodology was used. The results show that internalized costs for the first year for the 500 MW CHP plants account for 7% of total production costs.

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Keywords: CHP plants, external costs, internalized costs, energy production cost structure

1. Introduction

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Electricity is more a necessity for the end-users than many other commodities [1]. In the total available electricity in Croatia, about 70-75% of electricity originates from own production, while about 1/3 of electricity is imported. Due to deterioration, thermal power plants with almost 1,100 MW will cease to operate and until 2020 it is planned to build cogeneration units with the total power of at least 300 MW in back pressure mode [2]. Having in mind the proclaimed goals of the EU until 2020, i.e., 20% of energy from renewable sources, a 20% increase in energy efficiency, and a 20% decrease in greenhouse gas emissions [3], it is important that these new facilities would be the state-of-the-art technology.

The construction and operation of combined cycle heat and power (CHP) plants generate both positive and negative effects on the environment and society as a whole (external benefits and external costs, respectively). Bachmann and van der Kamp [4] state that in the case of electricity generation in combustion plants, external costs arise if the costs of the resulting environmental impacts are not covered or compensated for by the plant operator (i.e., reflected in the price of electricity). If those costs are not internalized in the price for energy supply, suboptimal consumption of energy occurs from a socio-economic perspective [5]. Internalization of external costs in most cases is made through different taxes or fees. They highly depend on the applied power production technology [6].

The process of electricity generation can be divided into four sub-processes representing the life cycle stages: power plant construction, fuel supply, power plant operation and power plant dismantling [7]. This paper aims at quantifying internalized costs that an investor has to pay for the first project year of a CHP plant named the Combined Cycle Heat and Power Plant "KKE Osijek 500" (hereinafter referred to as the 500 MW CHP plant) in Croatia. This power plant will be used to generate electricity, primarily for Eastern Croatia, and process steam and district heating for the city of Osijek. Its energy source will be natural gas and the required efficiency is expected to exceed 58% [8]. The construction is planned to start in 2015 or in early 2016. Furthermore, in this paper, a structure of energy production costs will be analyzed as well as the impact internalized costs have thereon.

The remainder of the paper is organized as follows. Section 2 describes the methodology used to carry out the present study. Section 3 provides a concise overview of the internalized costs of energy generation in Croatia and their estimates for the 500 MW CHP plant. Section 4 examines the energy production cost structure and briefly discusses implications an increase in internalized costs could have thereon. The conclusions are given in Section 5.

2. Methodology

To define the various social costs associated with the operation of a CHP power plant, the ExternE methodology was used following many other researchers [1, 4, 9]. The methodology, implemented in five stages [10], covers the following external effects: environmental impacts (on human health, crops and loss of biodiversity), global warming impacts and accidents as well as energy security.

Among three approaches for estimating external costs described in ExternE (the impact pathway approach, the standard price approach and the top-down approach), the impact pathway approach (IPA) was followed in this paper. There is consensus among the scientific community that this approach should be followed provided that sufficient data and information are available [11]. The IPA approach starts with estimating emissions from a source, then expressing those impacts in physical units and finally converting those physical units into monetary terms.

The 500 MW CHP plant was used as a case study in this paper. An operation concept for it is described in the Environmental Impact Study (2014) [8]. The 500 MW CHP plant will be a combined cycle heat and power plant with the power of 500 MWe, thermal power of 160 MW heat, and process steam of up to 40 t/h. For the purpose of calculating internalized costs for this CHP plant several assumptions were followed in this paper:

- approximately 6,970 working hours on a yearly basis,
- internalized costs were calculated for the first project year,
- 0.202 tons/MWh of CO_2 emissions,
- 108 kg/h of NO_2 emissions,
- the difference between water taken and water released after the process is 199,502 tons/year,
- the amount of water taken from the Drava River for cooling purposes amounts to 9.3 m^3/s,
- the exchange rate of HRK 7.52 for € 1 was used.

3. Internalization of External Costs in Energy Generation in Croatia

When expressing negative or positive external effects in monetary units, these are termed external costs or benefits, respectively [4]. These external costs are not accounted for by the decision maker; thus, they should be internalized by using appropriate instruments [10]. Similarly, external costs of electricity generation represent the uncompensated monetary value of environmental and health damages it causes [12]. The best way of internalizing these costs is via imposing taxes or fees that are equal to external costs, so that prices reflect the true costs and tell the ecological truth [10]. Therefore, internalization is a result of the use or protection of environmental components, primarily air, soil, water, natural habitats, flora and fauna and landscape.

Internalized costs that an investor in a CHP plant needs to pay in Croatia for the first project year include those related to the impact on water (the water regulation fee, the water usage fee, the concession fee for water usage, the water protection fee), air (purchase of a carbon dioxide emissions quota, the emissions fee for nitrogen oxides expressed as nitrogen dioxide), and land (the fee for the use of land used by power plants, the fee for the waste disposed in the environment, and the fee for the change of use of agricultural land). Bearing in mind that they represent only a part of external costs, their description and amounts an investor has to pay for the 500 MW CHP plant are as follows.

Water regulation fee. Water regulation fee is paid by owners or other persons authorized to use or manage real estate. It is regulated by the Regulation on the amount of the water usage fee [13] and the Ordinance on calculation and collection of water usage fees [14]. The water regulation fee is used in the water area where it is paid, and the basis for calculation of the water regulation fee is one square meter of the subject real estate. The annual water regulation fee for the first project year amounts to € 971.

Water usage fee. Water usage fee is paid by users for the abstraction and exploitation of water from its natural deposits and for its usage for various purposes. Pursuant to Article 2 of the Ordinance on calculation and collection of water usage fees [14], the water usage fee has to be paid by the investor, since (s)he takes water for cooling in the technological process.

The Regulation on the amount of the water usage fee [13] and the Regulation on amending the Regulation on the amount of the water protection fee [15] determine the amount of the water usage fee and correction coefficients which reduce the amount of the water usage fee. The total amount of the fee that must be paid is determined as a multiple of the amount of the water usage fee and the quantity of water in m^3 for the calculation period. According to Article 5, paragraph 3, of the Ordinance on calculation and collection of fees for water protection [14], the amount of water is determined according to the total amount of water which is lost in the process of cooling, that is, as a difference between water taken and water released after the process.

The difference between water taken and water released after the process is 199,502 tons and thereby the annual water usage fee for the first project year amounts to € 19,101.26.

Concession fee for water usage. According to the Concessions act [16], the right to economic use of general or other resource, which was stipulated by the law to be in the interest of the Republic of Croatia, is acquired through concession. Therefore, it is necessary to obtain concession for economic utilization of

waters. The regulation which regulates this is the Regulation on terms and conditions of giving concessions for economic water use [17]. This Regulation defines, inter alia, the conditions of giving concessions from Article 163, paragraph 1, of the Waters Act, the period for which the concession is given, the lowest amount of the concession fee and the method of determining the concession fee. The competent body for issuing concessions is the Government of the Republic of Croatia, namely the Ministry of Agriculture, Forestry and Water Management, and the contract is concluded with the State Directorate for Water Management. For the abstraction of water for utilization for technological and similar purposes, e.g., in technological processes (water as a raw material) and for similar purposes, in the amount of over 1,000 cubic meters (m^3) per year, and for the purpose of cooling in technological processes, the concession period is up to 30 years.

The concession fee comprises the annual fee and a one-time fee. For the abstraction of water for utilization for technological and similar purposes, the annual fee is calculated on the basis of amount of abstracted water and it amounts to 10% of the water usage fee, which is paid according to the Act on Water Management Financing. For the abstraction of water for technological and similar purposes, the one-time fee cannot be less than the five-fold amount of the annual fee determined according to the amount of water for which the concession is given. Since the concession fee amounts to 10% of the water usage fee, the investor has to pay € 1,910.13 yearly, while a one-time fee amounts to € 9,550.65.

Water protection fee. Water protection fee is paid by the beneficiary for water pollution, i.e., the change of water quality which occurs through intake, release or storage of nutritive and other compounds into water, through the influence of energy or other causes, in the amount which changes the useful characteristics of water, worsens the situation of water ecosystems and limits the purposeful utilization of waters.

According to the Regulation on amending the Regulation on the amount of the water protection fee [15] which became effective on 1 January 2013, the fee amounts to 0.00135 HRK/m^3 for released water used in the process of cooling. The basic amount of that fee is the same for the entire Republic of Croatia and it is calculated according to the released quantity of water determined by measuring on metering devices, and, if necessary, by expertise or assessment. Entities which have installed water purification devices that serve the intended purpose will have the amount of fee reduced. Pursuant to Article 2 of the Ordinance on calculation and collection of fees for water protection [14], the amount of fee (N) is calculated according to the formula: $N = T\Delta t \times Vt \times \Delta t$, where $T\Delta t$ is the amount of fee for 1 m^3 of released water used in the process of cooling, determined by the Regulation on the amount of the water protection fee (0.00135 HRK/m^3), Vt is the annual quantity of released waste water which is used in the process of cooling in m^3, and Δt is the difference between the arithmetic median values of the waste water temperature at release and the abstraction water temperature during one year.

Thereby, the water protection fee for the first project year amounts to € 335,069.

Purchase of a carbon dioxide emissions quota. With the access of the Republic of Croatia to the European Union and joining the European system of emissions trading from 1 January 2013, there exists a liability for buying emission quotas for every ton of emitted carbon dioxide [18]. The start of the mandatory purchase of emission quotas denoted the end of the carbon dioxide emissions fee defined by the Regulation on unit fees, corrective coefficients and closer criteria and parameters for determining the fee referring to carbon dioxide emissions into the environment [19]. The purpose of the collected funds is to increase energy efficiency, invest into renewable energy sources, develop technologies for reducing greenhouse gas emissions, etc.

In this paper, the expected market price of emission of a ton of CO_2 was estimated to 10 €/t. Thereby, the annual purchase of carbon dioxide emission quotas for the first project year amounts to € 11,020,334.

Emissions fee for nitrogen oxides expressed as nitrogen dioxide (NO_2). The emissions fee for nitrogen oxides expressed as nitrogen dioxide (NO_2) is defined by the Regulation on unit fees, corrective

coefficients and closer criteria and parameters for determining the emissions fee for sulfur oxide expressed as sulfur dioxide, and nitrogen oxide expressed as nitrogen dioxide, released into the environment [20]. Tributaries of payment are determined and calculated the amount of emission of NO_2 and the corrective encouragement coefficient separately for each discharge. Tributaries pay the fee determined collectively for all discharges.

On the basis of estimating the annual amount of NO_2 emissions and the unit fee for a ton of discharged NO_2, the annual emissions fee is estimated (according to the same Regulation, since 1 January 2006, the unit fee for a ton of NO_2 emissions amounts to 310 HRK) and it amounts to € 31,025 for the first project year.

Fee for the use of land used by power plants. Fee for the use of land used by power plants is regulated by the Electricity market act [21] and by the Decision on the amount of the fee for the use of land used by generation facilities for electricity generation [22]. It is the local government revenue. The amount of the fee is a multiple of a coefficient and the quantity of electricity produced at a plant gate. A one-year fee for the first project year amounts to € 3,488,696.81.

Fees for waste disposed in the environment. Fees for waste disposed in the environment include: 1) the fee for municipal waste and/or nonhazardous technological (industrial) waste, and 2) the fee for hazardous waste. The fee for waste disposed in the environment is regulated by the Law of Environmental protection and energy efficiency fund [23], Determination of charges for burdening the environment with waste [24] and the Ordinance on the method and terms for calculation and payment of charges for burdening the environment with waste [25]. The fee for waste disposed in the environment is the revenue of the Environmental Protection and Energy Efficiency Fund.

The hazardous waste fee is calculated and paid according to the quantity of produced but not processed or not exported hazardous waste and according to waste characteristics, pursuant to formula: $N = N_1 \times P \times k_k$, where N represents the amount of the hazardous waste fee in HRK, N_1 is the fee for one ton of produced but not processed or not exported hazardous waste (a unit fee), P is the quantity of produced but not processed or not exported hazardous waste in one calendar year, k_k is the corrective coefficient based on hazardous waste characteristics. Hazardous waste fees are paid for one calendar year.

According to the Regulation on unit charges, corrective coefficients and detailed criteria and standards for determination of charges for burdening the environment with waste, a unit fee for one ton of disposed nonhazardous technological (industrial) waste amounts to 12 HRK. Thereby, a one-year fee for waste disposed in the environment amounts to 10,624.48 HRK (885.14 ton x 12 HRK/t), i.e., € 1,412.46.

Fee for the change of use of agricultural land. This fee is charged because of the decrease in the value and area of agricultural land which is a resource of interest to the Republic of Croatia. The procedure for the change of use of agricultural land is regulated by the Agricultural land act [26]. For the purpose of changing the use of agricultural land, its quality is taken into account (particularly valuable (P1) or valuable (P2)), as well as the fact whether the land is located inside/outside the buildable zone and whether it is in a spatial plan within the buildable zone. According to the new Act, in this case it is particularly valuable (P1) and valuable (P2) agricultural land within the buildable area. The total land area that should be changed is 148,971 m^2, and the estimated purchase value is 3 million €. According to the Act, a one-off fee for the change of use of agricultural land amounts to 5% of the land value, i.e., € 150,000.

Internalized costs of the 500 MW CHP plant in Croatia amount to € 15,058,070.31 for the first project year. Their share in the total energy production costs will be calculated in the next section.

4. 500 MW CHP Plant Production Cost Structure

The basic categories of production costs of the 500 MW CHP plant include fuel, maintenance costs and costs associated with fixed-asset investments (amortization). Their amounts are explained and calculated in detail in the Investment program [27]. Besides those basic categories, energy production costs also include internalized costs which are described in the previous section. Table 1 shows an overview of the production cost structure of the 500 MW CHP plant.

Table 1: Share of the main production costs of the 500 MW CHP plant in total production costs

Cost	Structure (%)	Cost	Structure (%)
Fuel costs	64.21	Costs for CO_2 and NO_x emissions	5.17
Financial costs	10.63	Land fees	1.63
Amortization	10.42	Cooling water costs	1.28
Maintenance costs	4.68	Water fees	0.17
Administrative, service and immaterial costs	1.63		
Salaries	0.18		
Total			100.00

As could be seen in Table 1, internalized costs that an investor has to pay make approximately 7% of the total operating costs of the 500 MW CHP plant (0.0051 €/kWh). The main share of those costs accounts for the costs associated with CO_2 and NO_x emissions (5.17%). The share of internalized costs in the total operating costs is, e.g., higher than the share of CHP maintenance costs, which are around 5%. Butti et al. [6] highlight that external costs in Croatia are relatively low, i.e., € 1.76 kWh (prices in 2007), primarily due to intensive use of hydroelectric power. In ExternE studies, external costs for gas were estimated in the range between 1 and 4 Eurocents/kWh; in NEEDS study [28], external costs for new gas facilities were between 0.7 and 4.7 Eurocents/kWh, while the European Environment Agency [29] estimated external costs for advanced gas technologies at 1.1 Eurocent/kWh. If all the external costs would be internalized, their proportion in the total operating costs would definitely affect the energy production cost and consequently maybe the selling price. For example, Georgakellos [1] concluded that possible internalization of external costs associated with CO_2 emissions in Greece would increase the electricity production cost by more than 52%.

Further research could be done in order to show what the impact of internalization of most external costs would be on energy production costs in flexible, reliable and technology superior CHP plants. Moreover, using simulation models, such as EcoSenseWeb, external costs could be estimated and then compared to internalized costs to see which part of external costs needs to be internalized.

5. Conclusion

With the aim of estimating internalized external costs of a CHP plant, an example of such plant called "KKE Osijek 500" was used. Internalized costs were grouped into three categories, depending on their impact on water (the water regulation fee, the water usage fee, the concession fee for water usage, the water protection fee), air (purchase of a carbon dioxide emissions quota, the emissions fee for nitrogen oxides expressed as nitrogen dioxide), and land (the fee for the use of land used by power plants, the fee for the waste disposed in the environment, and the fee for the change of use of agricultural land). The analysis showed that in the total energy production costs, internalized costs accounted for around 7% of the total costs (0.0051 €/kWh) for the first project year. If those costs were compared to the estimate

made by the European Environment Agency, a small amount of external costs of the CHP plant in Croatia is internalized. If these costs were internalized to a greater extent, this would affect investor's earnings as it would be necessary to reduce his/her profit margin while maintaining the existing electricity selling price. If he were to decide to increase the electricity selling price, it would have an impact on security of energy supply, its affordability and price competitiveness as well as the overall economic and social activities in Croatia. Alternatively, the investor could decide not to invest in a new CHP plant but in other projects, such as renewable energy sources for which abundant support schemes exist.

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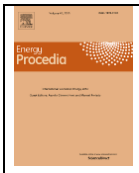

Biography

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